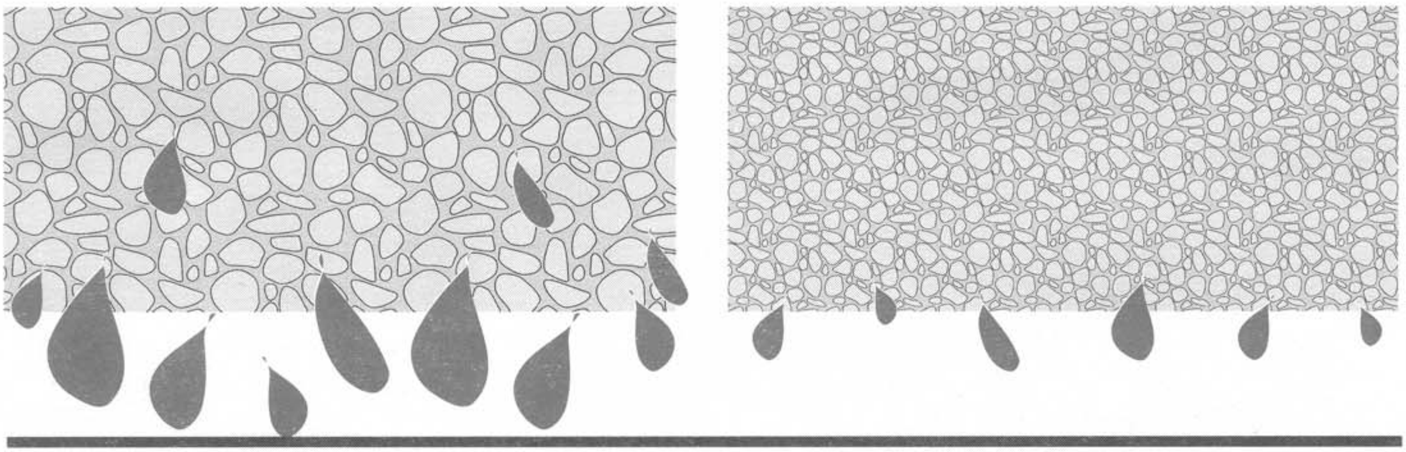
How Groundwater Moves



Porosity and Permeability

Goals: To help students understand how characteristics of soil particles (e.g., size and shape) affect the porosity and permeability of soil and thus, groundwater storage and movement.

Subjects: Science, Math

DPI Objectives: SC: A1-A3

Grades: 6-9

Materials:

- ❖ Porosity and Permeability activity sheet
- ❖ gravel*
- ❖ sand*
- ❖ clay*
- ❖ potting soil*
- ❖ containers for used clay, soil, sand and gravel

For each group of 2-3 students:

- ❖ 4 test tubes
- ❖ test tube rack
- ❖ 100 ml glass beaker
- ❖ small funnel
- ❖ 100 ml graduated cylinder
- ❖ 4 sheets of round filter paper
- ❖ glass marking crayon

* These materials must be very dry. Spread soil materials on a cookie sheet and dry in oven at 250-275° F. Break up clay and potting soil after drying so that no clumps remain.

Background: Just how solid is "solid ground?" The material beneath our feet is rarely solid. Soil is made up of particles of rock and the spaces between these particles. The amount of space between soil particles is called porosity. You can estimate the porosity of a soil by measuring the amount of water it can hold.

Underground, water percolates down through soil and flows from higher elevations (such as a hill) to lower elevations. The ease with which water moves through a soil or rock type is called *permeability*. You can estimate the permeability of soil by timing how quickly water can flow through it.

Physical characteristics of soil particles, such as size and shape, influence the porosity and permeability of soils and rocks. Coarse materials, like gravel and sand, tend to be both porous (they have large pore spaces that can fill with water) and permeable (water passes easily between the large particles). Some fine materials, such as clay, may hold a lot of water yet transmit very little because water cannot move easily through the tiny pore spaces.

An *aquifer* is a rock or soil formation that can both store and transmit a significant amount of water. A well drilled in a sand aquifer is likely to yield a lot of water; a well drilled in clay will probably yield little.

Procedure:

A) Predicting porosity and permeability.

1. Examine the gravel, sand, soil and clay. Predict which materials can hold the most water and which ones water will flow through fastest. Record your predictions on the chalkboard. Then, in small groups, either investigate each material or assign groups to one soil material and compile class results on the chalkboard.

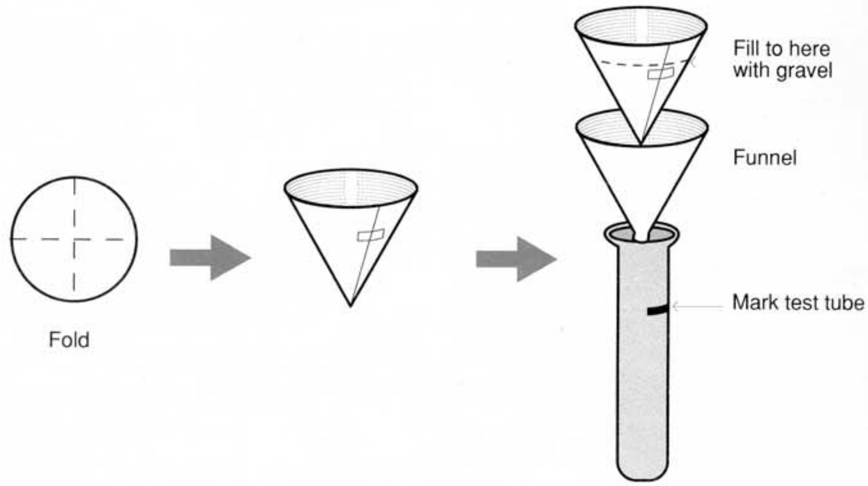
B) Measuring porosity.

1. With a marking crayon, place a line about 1/2 way up the side of a small beaker. Fill the beaker with water to the line. Pour this water into a 100 ml graduated cylinder. Record this volume on your data sheet under "total volume." Dry the beaker.

2. Fill the beaker with gravel to the line and fill the graduated cylinder to the 100 ml mark with water. Pour water from the graduated cylinder into the beaker until it reaches the line. Record the volume of water needed to saturate (fill the pores of) the gravel on your data sheet under "pore space." Divide this volume by the "total volume" and multiply by 100 to get percent pore space in your sample of gravel. Record this value under "porosity" (% pore space). Repeat the investigation with samples of sand, soil and clay. (Note: For potting soil and clay, make sure that the water has time to soak in completely.) Record your results.

C) Measuring permeability.

With a marking crayon, place a line about 1/2 way up a test tube. Put the test tube in the rack and put the stem of a small funnel inside the test tube. Fold a circular filter paper into quarters, open it into a cone, and insert it into the funnel. Fill the cone with gravel to about 1/2" from the top. Pour water from a beaker into the filter. Using a clock, a watch or by counting, time how long it takes to fill the test tube to the line. Record the results on your data sheet under "permeability." Return the sample of gravel to the used gravel container and discard the filter paper. Repeat the experiment with sand, soil and clay.



Make bar graphs of your results and complete questions on the "Porosity and Permeability" activity sheet. Discuss your results and answers:

- ❖ Did your results match your predictions?
- ❖ Which material is the most permeable? Why?
- ❖ Which is the least permeable? Why?
- ❖ Which soil is the most porous? Why?
- ❖ Which is the least porous? Why?
- ❖ If you drilled a well in these materials, which one do you think would yield the most water?

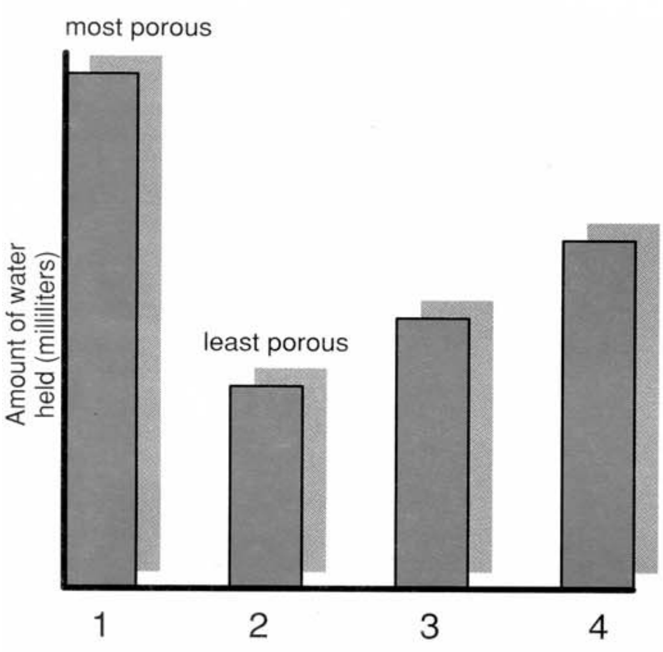
Going Beyond:

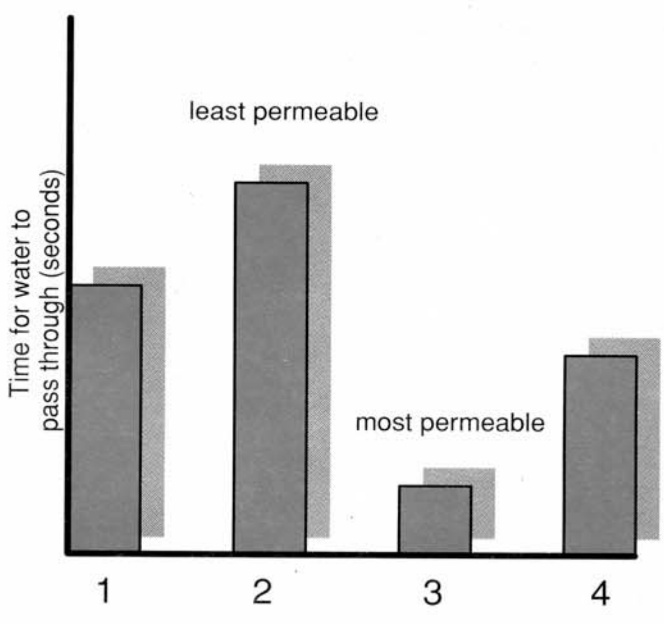
1. Invite a certified soil tester or county on-site waste disposal (septic system) specialist to discuss how porosity and permeability of soil and rock are measured in the laboratory and in the field.

2. Compare the porosity of a variety of rocks. Record the weights of small pieces of limestone, sandstone, shale, granite, obsidian, lava, etc. Soak the rocks in water for several days. Remove them from the water and pat them dry. Weigh the rock pieces again and record your results. Compare the mass of each rock before and after soaking. Discuss your results in terms of the rock's ability to hold water. Note: water may move through cracks in rock as well as through the pore spaces. The amount of cracking in a rock determines its "secondary porosity."

3. Investigate the effect of organic material on a soil's permeability and its ability to filter contaminants. Prepare four "contaminated" water samples containing 1) vegetable oil, 2) vinegar, 3) detergent and 4) green food coloring. Pour small amounts of each sample through 1) sand, 2) sand + potting soil, 3) clay, 4) clay + potting soil. Compare filtering times of the different soils. Compare appearance of contaminant samples before and after filtering (use pH paper for vinegar). Filter plain tap water as a control.

Adapted from: ***Groundwater: A Vital Resource****. Cedar Creek Learning Center and the Tennessee Valley Authority.*





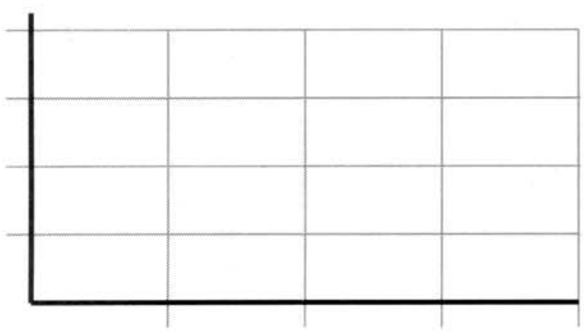
Porosity and Permeability activity sheet

A. Complete the following table:

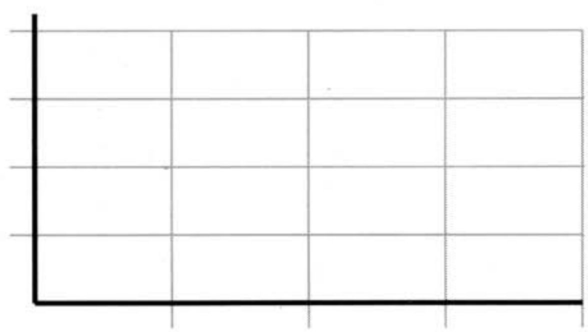
Material	Total Volume (mililiters)	Pore Space (mililiters)	Porosity (% Pore Space)	Permeability
Gravel				
Sand				
Soil				
Clay				
Porosity = (Pore Space ÷ Total Volume) x 100				

B. **Make bar graphs of your results.** Label the axes on your graphs (don't forget to add the units).

Porosity



Permeability



* Remember, the material through which water takes the longest time to flow is the LEAST permeable.

C. Answer the following questions:

1. Which material is **most** porous? ______________________________

2. Which material is **least** porous? ______________________________

3. Rate the materials in terms of their permeability.

1 ______________________________ (Least permeable)

2 ______________________________

3 ______________________________

4 ______________________________ (Most permeable)

4. How does soil type affect the movement of groundwater?

5. Do you think soil can help protect groundwater from pollution? If so, how?